Research on marine bivalves in the People's Republic of China

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Abstract. This paper summarizes the published literature on marine bivalves in the People's Republic of China from 1950 to 1991. The 221 citations listed in the bibliography contain only significant works as viewed by the author. The summary includes systematic research on 23 families of bivalves distributed in the Chinese seas and encompasses the Arcidae, Glycymerididae, Limopsidae, Mytilidae, Pinnidae, Pteriidae, Isognomonidae, Pectinidae, Plicatulidae, Ostreidae, Chamidae, Cardiidae, Tridacnidae, Mactridae, Mesodesmatidae, Tellinidae, Solenidae, Veneridae, Myidae, Corbulidae, Pholadidae, Teredinidae and Laternulidae.

The breeding biology and experimental ecology of 12 economically important bivalves is addressed for the following species; *Crassostrea rivularis* (Gould), *Crassostrea gigas* (Thunberg), *Mytilus edulis* (Linnaeus), *Perna viridis* (Linnaeus), *Sinonvacula constricta* (Lamarck), *Tegillarca granosa* (Linnaeus), *Chlamys farreri* (Jones and Preston), *Chlamys nobilis* (Reeve), *Argopecten irradians* (Lamarck), *Ruditapes philippinarum* (Adams and Reeve), *Pinctada martensii* (Dunker), and *Pinctada maxima* (Jameson).

China is a large coastal country, with 18,000 kilometers of coastline, a vast expanse of seas, and over 14,000 kilometers of islandic coastline. There are four seas, the Bohai Sea, the Yellow Sea, the East China Sea and the South China Sea, with an area of 4.75 million square kilometers, including more than 6,000 islands. Marine bivalve resources are very rich throughout the region.

Three marine molluscan faunal provinces for China seas have been identified: 1) a warm temperature region that includes the Yellow Sea and Bohai Sea; 2) a subtropical region that includes the East China Sea, the north-western coast of Taiwan and the northern coast of Hainan; 3) a tropical region including the south-eastern coast of Taiwan, the coast of the southern tip of Hainen Island and the area south of them.

The suffix to this paper offers more than 200 citations concerning Chinese marine bivalves. This obviously does not include the entire Chinese bivalve literature but rather a circumspect summary of the significant works. The majority of the papers were written in Chinese, with English abstracts or with English headings only, though a small number were written in English. There have also been several articles that were published in general magazines, but are not included in this summary.

SUMMARY OF MARINE BIVALVE RESEARCH IN CHINA

1. Systematics and Biogeography

In China, the study of marine bivalve taxonomy started much later than in western Europe. Before October 1949 (The Liberation), foreign and domestic scientists had published few comprehensive systematic works. However, between 1950-1990, 40 years were dedicated to intensive sampling and investigation along China's coastal seas, that is, starting from the most northern sea, the Yalu River Estuary, to the southern most area, the Xisha Islands. Between 1958-1960, a nation-wide general exploration was completed in the coastal seas; from 1959 to 1962 an investigation on the Beibu Gulf of the South China Sea was completed. Owing to the extensive number of sampling stations and frequency of seasonal investigation, a large number of specimens were obtained. These specimens have been identified and are housed currently in the Institute of Oceanology, Academia Sinica. Thanks to the extended collecting plan, we have been able to report on the distribution of Chinese coastal and near sea bivalves and summarize the zoogeography of the region. From 1980-1984, under the leadership of Chinese National Bureau of Oceanography, these investigations were completed. The above work was done by relevant universities of the coastal provinces, each with a mission to collect and preserve large numbers of samples. The investigation of the coastal regions was also combined with sublittoral zone research (0 to 5 m). Further, since 1990, the Chinese National Bureau of Oceanography has been organizing the coastal provinces to launch large-scale islandic investigations. Further study is anticipated on the coastal resources, followed by a program of marine bivalve resource development and utilization.

Marine bivalves hold an important position among marine molluscs, due to their use as a human food and as feed for domestic fowl and prawns, and thus they are viewed as a key resource in the national economy. Our research is based primarily on bivalve species that can be developed for a market economy or have some economic impact, such as members of the Ostreidae and Teredinidae. Many articles have been published in China about the breeding, growth and ecology of *Crassostrea rivularis* (Gould, 1861), and *Teredo navalis* Linnaeus, 1758, resulting in enhanced oyster breeding and a shipworm prevention and treatment program.

Additional research on marine fisheries, physical oceanography, and pollution has yielded large numbers of specimens that can be used for detailed studies of the systematics, ecology and zoogeography of bivalves. On the basis of these scientific materials, taxonomists have published many monographs and treatises on a variety of families and genera, and have discovered and described many new genera and new species. As basic survey work continues, taxonomists continue to engage in systematic research on the families that have economic value, such as the Arcidae, Mytilidae, Pinnidae, Pectinidae, Mactridae, Veneridae, Tellinidae, Pholadidae, Corbulidae, Laternulidae and Myidae.

2. Biology and Ecology

The biology and ecology of intertidal and infaunal benthic bivalves has been superficially studied. Naturally, there has been some analysis of the variation in mollusc species composition and density. The ecology and biology of local species of *Donax*, *Moerella* and *Cultellus* has been studied, and the population structure of *Perna viridis* (Linnaeus, 1758) has been examined in several regions.

General research on benthic community structure in three inner bays in the Bohai Sea, has yielded data on the relatively high densities of *Scapharca subcrenata* (Lischke, 1869); *Chlamys farreri* (Jones and Preston, 1904), *Atrina pectinata* (Linnaeus, 1758), and *Paphia undulata* (Born, 1778), suggesting possible sites to develop and utilize in the future.

3. Experimental ecology and mariculture of economically important species

Oysters. The literature on Ostreidae breeding far exceeds that of other families. The primary species utilized in China are *Crassostrea rivularis* and *C. gigas* (Thunberg, 1793). *C. rivularis* is common in the Pearl River Estuary, and is the primary species harvested in Guangdong Province. It is also found in lower densities in the Fujian Province. Results of research on the feeding habits, breeding seasons, predators, and artificial rearing of larvae are included in the literature reviewed below. Beside the traditional cultivation method of "throwing stones", a new raft culture technique has produced high yields. *C. gigas* is a well known species in the Fujian Province, and reports on its culture were recorded in Xiapu County in the early 16th Century. The annual harvest of this species in 1986 was 44,200 tons.

Mussels. There are three species of economically important mussels in China: the Purple mussel, *Mytilus edulis* Linnaeus, 1758; the Hardshell mussel, *M. crassitesta* Lischke, 1868; and the Jade mussel, *Perna viridis*. *M. edulis* is distributed in north China, *M. crassitesta* is distributed in Liaoning, Shangdong and Zhejiang Provinces, but *P. viridis* is found only in Fujian and Guangdong Provinces.

Cultivation of marine mussels began in China in 1958, at which time studies were undertaken to study mytilid life history, feeding habits, sexual maturation, growth, meat condition, method of culture, development of larvae, and artificial rearing of spat. Mussel rearing conditions, feeding requirements and treatment of larval culture water has been reported in numerous publications. Artificial spat rearing of these three mussel species has been successful.

The primary mussel breeding technique in China utilizes hanging rafts. Due to the large acreage devoted to culture, juveniles are usually collected from sea-weed rafts. New types of ecologically sound breeding programs have been tested, such as combined mussel-seaweed culture, where the nitrogenous waste products of mussels are utilized as fertilizer for the sea-weed, and in turn the growth of the seaweed improves the mussel culture.

Chinese Razor Clam. *Sinonovacula constricta* (Lamarck, 1818) lives in coastal waters with lower salinity than usually found in the northern and southern mid-littoral zones, however, artificial breeding of razor clams has been successful in the Zhejiang and Fujian Provinces. Traditional culture techniques have been practiced in those areas where the juvenile clams naturally settle, allowing easy collection, redistribution and harvest. By the end of the 1950's, malacologists had examined the reproductive biology of razor clams. Analysis of these data has provided an effective forecast system for rake flat productivity, and has allowed the establishment of harvest quotas. In this way, the number of clams harvested has been increasing. From 1970-1980, malacologists experimented with natural juvenile collection. These studies included monitoring temperature, salinity, the relationship between rate of survival of juvenile clams and growth, as well as the influence of the environment on the rate of razor clam incubation and the rate of gonad maturation.

Ark Clams. *Tegillarca granosa* (Linnaeus, 1758) is widely distributed along the Chinese coast, with artificial breeding mainly occurring in the Zhejiang, Fujian and Guangdong Provinces. Traditionally, the Shangdong Province supplies juvenile bloodclams that are then dispersed in the mid-lower intertidal zone and fed until they reach a preset size, after which they are spread, taking 1-2 years to reach marketable body weight (500 gms/80 shells). A production of 750 - 4,500 kg/mu is an optimistic yield. Extensive study on this species has been neglected and further investigations are desirable.

Scallops. Three species within the Pectinidae are commercially exploited in China, *Chlamys farreri* (Jones and Preston, 1904), *C. nobilis* (Reeve, 1852) and *Argopecten irradians* (Lamarck, 1819). *C. farreri* is distributed throughout the Yellow Sea and Bohai Sea, as well as to the south of the East China Sea, along the eastern Zhejiang coastal sea. *C. nobilis* is mainly found in the coastal area of the Fujian and Guangdong Provinces, and *A. irradians* has been introduced from the United States.

The adductor muscle of *Chlamys farreri* is the only tissue used in the production of dried scallop muscle, *ganbei*. In the mid-1950's, the famous Chinese malacologist, Tchang Si, developed methods for studying the feeding and growth of scallops, and provided a good foundation for the culture of this species. In 1974, Chinese scientists began to collect natural scallop spat and successfully experimented with artificial feeding and cultural production of *C. farreri*. In 1979, artificial culture experiments produced 0.92 million spat/m^3. Many research laboratories in North China have continued investigations of reproductive cycles, natural spat collection, artificial breeding and the study of an immense standard seeding, which has pushed the scallop fishery to the verge of mass production. During this period, breeding methods were changed from rafting and hanging techniques to field spreading.

Chlamys nobilis is an economically important species that has been cultivated in South China. Owing to the success of artificial breeding, cultivation has been modified to a method similar to the one used in mussel culture, that is, growing scallops on seaweed rafts.

Argopecten irradians is an important species that originated from the Atlantic Ocean. This species grows rapidly and produces a marketable scallop (mean length of 5 cm) in one year. In 1982, Professor Zhang Fusui (Institute of Oceanology, Academia Sinica) introduced breeding stock of *A. irradians* and has had excellent results in North China, with a higher fecundity than usual. The species has gradually spread down to northeast Fujian, creating a system of autumn artificial spat setting suitable to the thermal limitations in South China. Currently scientists are conducting a series of large scale experiments on the development of high density spat-rearing for this species. In 1984, Professor Zhang and his colleagues introduced the Japanese scallop, *Patinopecten yessoensis* (Jay, 1857) into China in hopes of utilizing this species for the production of dried scallop adductor muscles *(ganbei)*.

Littleneck Clam or Flower Clam. *Ruditapes philippinarum* (Adams and Reeve, 1850) is distributed broadly along the Chinese coast. In the north, the intertidal and sub-tidal zones have large beds of this clam, however, this is primarily due to the presence of strict resource protection and planned gathering. Artificial culture has been seldom practiced. Nevertheless, the Fujian Province has an important project on the artificial breeding of the Littleneck clams, including research on reproduction mechanisms, spermatogenesis, influences of chemicals and sexual products on hastening parturition, life history, growth of spats, and feeding habits. Laboratory breeding success, combined with mass production needs, have facilitated experiments in outside earth ponds including egg production, larval cultivation, and mass field production.

Pearl Oysters. The major species in China is *Pinctada martensii* (Dunker, 1850), which is used in pearl culture and is an important enterprise in Guangdong, Guangxi and Hainan Provinces. Research on this species has encompassed artificial breeding techniques including nucleus insertion, induced polyploidization, and observation of gonads during triploidization. Scientists have successfully completed inter-species hybridization of *P. martensii*, *P. chemnitzii* (Philippi, 1847) and *P. maxima* (Jameson, 1901), and have studied hybrid chromosomes and their zymograms. Many studies have been undertaken on *P. maxima*. Owing to its scarce distribution in nature, large shell, and good quality and high priced pearls, artificial breeding experiments have been completed. However, it must be noted that many hurdles still must be overcome to utilize this species.

Along with the seven important bivalves mentioned above, research has begun on the breeding and ecology of other bivalves such as *Coelomactra antiquata* (Spengler, 1802), *Meretrix meretrix* (Linnaeus, 1758), *Mactra veneriformis* Reeve, 1854, *Musculus senhousei* (Benson, 1842), *Atrina pectinata* (Linnaeus, 1758), *Laternula marilina* (Reeve, 1860), *Saxidomus purpuratus* (Sowerby, 1852), *Scapharca broughtoni* (Schrenck, 1867) and *Potamocorbula laevis* (Hinds, 1843).

CONCLUSIONS

The study of systematics has naturally focused on families and genera that are economically important, leaving ignored several important families without commercial potential. Limited by restricted resources, we have only described species along the Chinese coast. Most studies have been limited to the identification of species, morphological descriptions, geographical distributions and a discussion of nomenclatural problems. The systematic treatment of superfamily and subspecific levels and the evolutionary relationships of bivalves have been inadequately studied. Moreover, most systematic research has been based chiefly on external morphology. The study of shell microstructure and functional morphology has been meager.

Due to the over emphasis of research on commercial species and the limited funding in general, the study of bivalve ecology has been neglected, especially research on autecology and synecology. Much attention has been paid to bivalve experimental ecology and breeding, but spat ecology needs further study. Facing the outside world and absorbing Euro-American advanced technology is required to enhance Chinese cultivation of marine bivalves.

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